



# Impact of Double-Crested Cormorant Predation on the Yellow Perch Population in the Les Cheneaux Islands of Michigan

By Glenn Y. Belyea, Susan L. Maruca, James S. Diana, Philip J. Schneeberger, Steven J. Scott, Richard D. Clark, Jr., James P. Ludwig, and Cheryl L. Summer

**Abstract:** The Michigan Department of Natural Resources, in conjunction with the University of Michigan and the U.S. Fish and Wildlife Service, initiated a research study to determine the impact of double-crested cormorants (*Phalacrocorax auritus*) on the yellow perch (*Perca flavescens*) population in the Les Cheneaux Islands area of northern Lake Huron. Aerial and nesting colony counts were conducted to monitor cormorant abundance. Creel census counts and tagging of 8,400 perch were used to study perch abundance. We collected 373 cormorants to study food habits via stomach-content analysis. We found that (1) cormorants fed heavily on yellow perch in early spring, but over the entire season only 10 percent of their diet was perch; (2) alewives (*Alosa pseudoharengus*) and sticklebacks (*Culaea inconstans*, *Pungitius pungitius*, *Gasterosteus aculeatus*) made up the major portion of the cormorants' diet;

(3) cormorants removed only 2.3 percent of the available perch biomass (*v.* 1.8 percent by anglers over the same period); (4) most fish taken by cormorants were less than 150 mm long; (5) total annual perch mortality was about 45 percent, of which less than 9 percent was due to cormorants; and (6) cormorants accounted for only 0.8 percent of the mortality of legal-size perch ( $\geq 178$  mm), whereas summer sport fishing accounted for 2.5 percent. Thus, although the impact of cormorants on the perch population may vary slightly from year to year, we conclude that cormorant predation had minimal impact on the local perch population.

**Keywords:** cormorant, double-crested cormorant, fish consumption, Michigan, *Phalacrocorax auritus*, predation, yellow perch

Since the late 1970's, the previously threatened double-crested cormorant (DCCO) has made an impressive comeback in the Great Lakes (Scharf and Shugart 1981, Ludwig 1984, Weseloh et al. 1995) and now numbers as many as 50,000 in Michigan waters alone (Ludwig and Summer 1997). From about 1940 through 1960, cormorants were almost extirpated from the Great Lakes due to dichlorodiphenyltrichloroethane (DDT)-related eggshell thinning and hatching deformities (e.g., Weseloh et al. 1983). The recent explosion of cormorants has been attributed to a reduction in the concentration of DDT and its metabolites in the water (Weseloh et al. 1995) as well as protection from human disturbance, increased nesting and foraging habitat on artificial reservoirs (Campo et al. 1993, Simmonds et al. 1995), and a ready food supply in the form of alewife in the Great Lakes (Price and Weseloh 1986, Ludwig et al. 1989).

Since 1980, diet studies in the Great Lakes show that alewife is the most prominent prey item for cormorants in nearly every location where alewife and cormorants are found together (Belonger 1983 unpubl., Craven and Lev 1987, Karwowski et al. 1992, Ludwig et al. 1989, Ross and Johnson 1995, Weseloh and Ewins 1994). Cormorants appear to be generalist feeders that consume prey species on the basis of

energetic profitability, which often results in the consumption of commercially or recreationally important species such as stocked trout or salmon (*Salmo* spp. or *Salvelinus* spp.), yellow perch, and walleye (*Stizostedion vitreum*).

Yellow perch populations have been declining in many areas of the Great Lakes for several decades, most likely as a result of repeated recruitment failures (Lucchesi 1988, Haas and Schaeffer 1992). Fisheries managers and sport anglers are both concerned that predation pressure from the abundant and growing populations of cormorants will either contribute to the further decline of yellow perch fisheries or prevent recovery (Diana and Maruca 1997).

In the Les Cheneaux Islands of northern Lake Huron, the perch fishery, which had for decades been economically important to the area (Diana et al. 1987), has experienced a marked decline since the late 1970's (Lucchesi 1988). In the mid-1980's, concern from anglers and local citizens helped generate a Michigan Department of Natural Resources (MDNR) study which revealed that growth overfishing (overharvest to the point that size at harvest declines dramatically) may have been at least partially responsible for the decline of the fishery (Lucchesi 1988). A 175-mm minimum size limit was instituted in 1987 in an effort to

reduce mortality for smaller fish, but it did not help the fishery as predicted (Schneeberger and Scott 1997). During this time, abundance of cormorants had increased in the area. Cormorants naturally reestablished at St. Martins Shoal, just west of the Les Cheneaux Islands, in 1980 after many years of absence. In 1995, the local population occupied three nesting colonies and numbered approximately 4,000 breeding pairs plus an estimated 2,000 to 3,000 juvenile birds (Ludwig and Summer 1997).

This project evaluated cormorant–perch interactions in Les Cheneaux Islands area. In particular, we studied population trends in cormorants and yellow perch and then determined the effect of cormorant foraging on the yellow perch fishery. Since the cormorant population expansion began 15 years ago, no studies on the Great Lakes have endeavored to examine cormorant diet composition, cormorant population dynamics, fish population size and mortality, and sport catch simultaneously. Without all of these pieces, the question of cormorant impacts on fisheries cannot be fully addressed.

## Study Area

The Les Cheneaux Islands are located on the north shore of Lake Huron east of the Straits of Mackinac near Cedarville, MI. The area consists of at least 23 islands surrounded by glaciated channels and bays that interconnect to form a physiographically diverse, largely oligotrophic aquatic ecosystem (Maruca 1997a). Aquatic habitats in the area fall into three general categories: shallow, productive inner bays (0 to 3 m); deeper channels and bays, often with some submergent vegetation (3 to 10 m); and deep outer bays and shoals more directly connected to Lake Huron (10+ m). Substrates in the area range from fine-grained silt and clay to coarse-grained pebbles and larger rocks. Most of the shoreline and original forest vegetation in the area have been disturbed as a result of development (Lucchesi 1988).

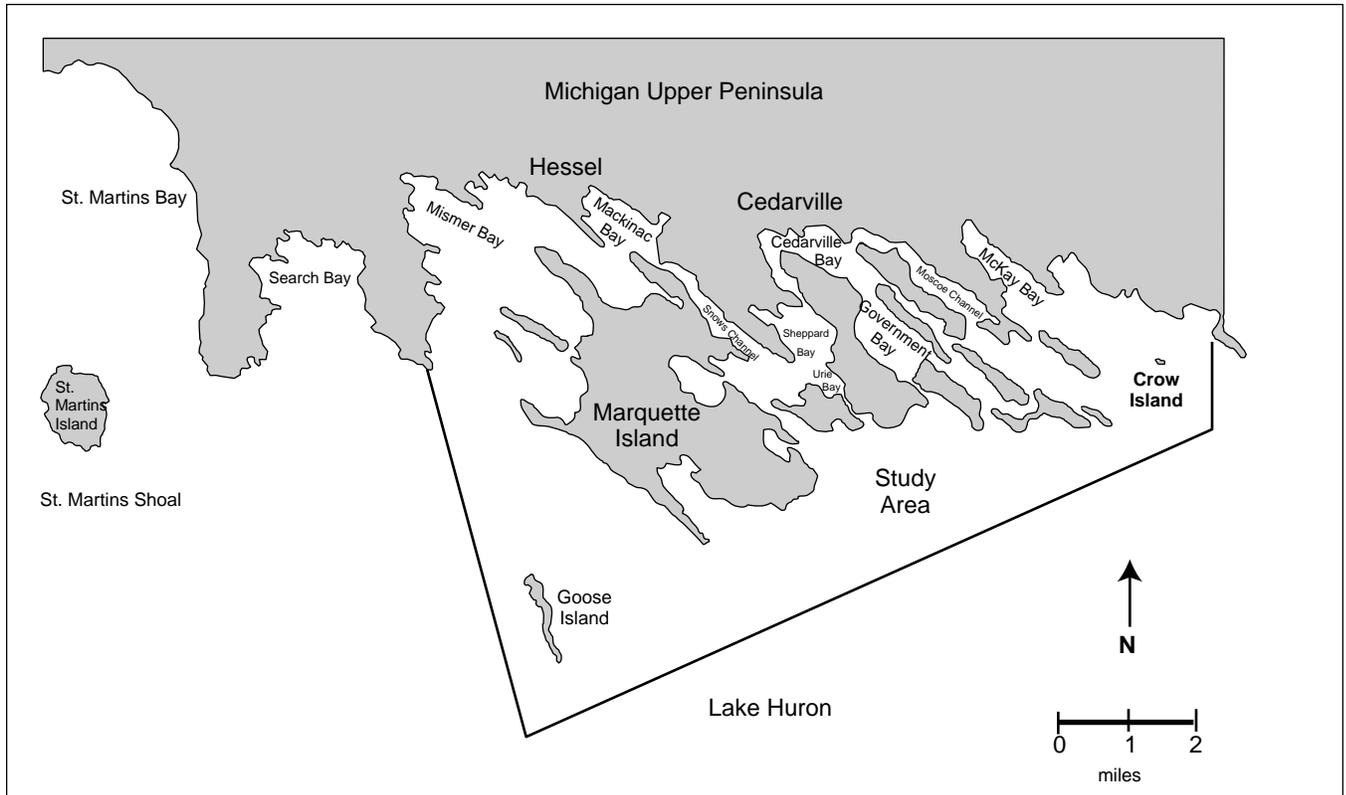
The study area boundary selected (fig. 1) was established in an effort to “encompass” the entire yellow perch population within the study area. Little information exists regarding yellow perch movements in the Les Cheneaux Islands area; however, Lucchesi (1988) found that none of the 11,649 yellow perch he tagged during spawning in Mackinac, Sheppard, or Flower bays were recovered outside the islands. The bounded study area contains approximately 11,860 ha (29,317 acres) of water (F. Chenier, pers. commun.), most of which is suitable yellow perch habitat. Cormorant colonies are located on Goose and Crow Islands, both contained within the study area, and on St. Martins Shoal, just west of the study area (Maruca 1997a).

## Methods

### *Cormorant Numbers*

Islandwide aerial surveys were conducted three times a week between April 17 and October 1, 1995 (Belyea 1997a). The approximately 163-km survey route covered all nesting colonies, bays, channels, and open lake areas within the study area. The surveys were flown by the same pilot in a Cessna 172 Superhawk at 7 a.m. and took about 1.2 hours. In total, 72 surveys were conducted. The beginning sampling scheme was developed using data previously collected by Soulliere and Maples (1994). The flight frequency was chosen based on variability of previous flights and the need to stratify by weekend or weekday. Flights were randomly allocated to 2 weekdays and 1 weekend day per week and were spaced to allow for 1 makeup day for bad weather per survey. Few of these makeup days were needed, and all were conducted on that alternate day. The pilot was experienced at making aerial cormorant counts, having flown numerous cormorant surveys for the Soulliere team in 1993 and 1994.

Accurate nesting colony counts required two to three visits per colony between late May and early July. Cormorants are one of the least synchronous breeders



**Figure 1**—The Les Cheneaux Islands study area in northern Lake Huron. Cormorant colonies are located on St. Martins Shoal, Goose Island, and Crow Island.

among colonial waterbirds and also are capable of rapidly replacing nests or eggs lost to predation. This lack of breeding synchrony applies both within and between colonies, making repeated colony counts essential. During each colony visit the number of nests was counted. In the colonies where nest contents were readily observable, clutch size data were also taken. During the July visit, all accessible, nearly full-grown young were leg banded.

### ***Cormorant Diet Composition***

Cormorant diet composition has been examined for several locations within the Great Lakes using nestling regurgitations and/or adult pellets (Belonger 1983 unpubl., Craven and Lev 1987, Christie et al. 1987, Ludwig et al. 1989, Karwowski et al. 1992, Ross and

Johnson 1995). In general, cormorant diets show a high degree of spatial variability and tend to reflect the fish species composition for each site, making it necessary to examine cormorant diets on a site-by-site basis. Although sampling diets using regurgitations and pellets is easier, faster, less expensive, and less destructive than sampling live birds, the information that can be drawn from these methods is limited (Maruca 1997b). Therefore, we chose stomach-content analysis as the most appropriate method to estimate cormorant diet composition for this study.

The stomach-content analysis was conducted using 373 cormorants sampled in 1995. From April 17 through October 6, on average, 15 birds per week were randomly shot within the study area. Stomachs from these birds were removed and preserved in 10-

percent formalin, and the contents were later identified in the laboratory. No more than 4 days elapsed between sampling dates. If possible, the sex of cormorants was identified in the field by examining gonads, although the sex of some birds was identified later by museum ornithologists, and the sex of others (especially immature birds) could not be identified. All birds were weighed. To minimize the number of empty stomachs obtained, birds were sampled either after they had been observed to forage for 20 minutes or as they were flying to the nesting colonies from the study area, presumably after feeding. Only 52 of the 373 stomachs were empty (14 percent), a figure lower than that observed for similar studies (e.g., Campo et al. 1993).

The species of prey items was identified when possible, with the exception of sculpins (*Cottus* spp.), shiners (*Notropis* spp.), and crayfishes (Astacidae). Meristic characters were used to identify intact fish; bones and bone fragments were used for digested prey items. Standards for bone identification were obtained from the fish skeleton collection at the University of Michigan Museum of Zoology.

Lengths of all intact fish were measured, except for sticklebacks and sculpins, for which subsets of approximately 100 fish per taxon were used. To provide more detailed length frequency information for yellow perch, lengths were estimated for many digested fish using cleithrum or preopercle lengths, and regressions for total length to bone length were

obtained from museum specimens. Of 184 yellow perch found in cormorant stomachs, 106 lengths were measured directly, 46 were estimated from cleithrum or preopercle lengths, and 32 were not obtained.

The weight of each intact fish was estimated using published length–weight regressions (Schneider et al. 1991) for all taxa except yellow perch. The weight of each digested fish was taken to be the average weight of all intact fish of that taxon. Weights were estimated as with other taxa, using length–weight regressions developed from yellow perch collected in the Les Cheneaux Islands area.

Cormorant diet composition was then determined by calculating the proportion by weight of each fish taxon in the diet (Maruca 1997b).

To characterize temporal variability of cormorant diet, 1995 was divided into six periods, each of which represented a qualitatively different diet and was separated from neighboring periods by observed habitat shifts (table 1). For example, from mid-April to mid-May, cormorants fed intensively in shallow (depth < 3 m) bays among the Les Cheneaux Islands. But from mid-May through the first of July, the birds fed almost exclusively in bays of intermediate depth (3–10 m) (Maruca 1997b).

The abundance of foraging cormorants was determined by estimating the proportion of birds from each colony that foraged in the study area. Ground observations of bird movements to and from each

**Table 1. Dates and qualitative descriptions of cormorant diet during six periods in the Les Cheneaux Islands area, Lake Huron, 1995**

| Period | Dates        | Number of days | Number of samples | Cormorant diet                                    |
|--------|--------------|----------------|-------------------|---|
| 1      | 4/17 to 5/16 | 30             | 85                | Spawning perch; pike and sunfish also important   |
| 2      | 5/17 to 7/3  | 48             | 97                | Stickleback and larger (age > 1 yr) alewife       |
| 3      | 7/4 to 8/1   | 29             | 67                | spawning alewife; many yearling alewife           |
| 4      | 8/2 to 8/19  | 18             | 44                | Diet highly diverse; alewife, sculpin, other prey |
| 5      | 8/20 to 9/13 | 25             | 53                | Young-of-year alewife, bullhead, and sunfish      |
| 6      | 9/14 to 10/6 | 23             | 27                | Young-of-year alewife, yellow perch               |

colony were conducted during May and June 1995. Each colony was observed on at least 4 different days and during as many different times of the day as possible within limitations set by weather patterns and travel time. Movements (arrivals or departures) were classified as “study area” or “other,” and the calculated study area usage was the mean proportion of study area movements weighted by the length of the observation period. Because no ground observations were made after July 1, we simply assumed that study area usages remained constant throughout the following months. It is possible, however—given the general observation that there were fewer birds feeding in the study area during late summer and fall—that usages declined during this time (Maruca 1997b).

Cormorant daily food consumption was estimated by dividing published daily calorie intake information (Dunn 1975, Hennemann 1983, Nagy 1987) by the caloric density of fish (Maruca 1997b). Yellow perch mortality from cormorant predation was then calculated using the daily caloric data together with cormorant population data and the proportion by mass of perch in the cormorant diet (Maruca 1997b).

### ***Yellow Perch Population Estimate***

During mid-April 1995, monel jaw tags were attached to 8,463 yellow perch in the Les Cheneaux study area. Fish were collected using 12 fyke nets set in about 1 m of water. Most fish (81 percent) were tagged in Cedarville Bay, and the rest were tagged in Mackinac Bay (13 percent), Flower Bay (3 percent), and Sheppard Bay (3 percent). Total length and sex were determined and recorded for each tagged fish (Schneeberger and Scott 1997).

Tag-return information was solicited from anglers by posting notices at launch sites and resorts. MDNR representatives met with local angling groups to encourage their cooperation with the tagging program.

We estimated the yellow perch population in the Les Cheneaux area using tag-return information and applying the Petersen formulas modified by Chapman (Ricker 1975) using number tagged (M), number of

recaptured tags (R), and number in sample (C). The Petersen population estimate was made using recapture data collected from July through October 1995. May and June data were excluded from consideration because catch and effort were relatively low in May and June and conditions justifying the validity of the Petersen application were better met using July to October data. The number of tag returns was multiplied by a correction factor of 1.7 to account for nonreporting (Schneeberger and Scott 1997).

### ***Yellow Perch Mortality***

Total annual mortality was calculated for yellow perch caught in gill nets during fall 1995 and aged from scale samples. Mortality was derived from coded age frequencies and formulas described by Robson and Chapman (1961). For comparison, and to determine if a discernible trend in mortality was occurring during the 1990's, we applied like methodology to gill-net catches from other years for which suitable data were available. In addition, we calculated a mortality rate from a pooled data set (1993 to 1995) to obtain an estimate having reduced potential bias associated with year-to-year recruitment variations. We calculated survival from tag-return data using Model 1 of the computer program ESTIMATE (Brownie et al. 1985), resulting in an independent derivation of total annual mortality (Schneeberger and Scott 1997).

### ***Sport Harvest Estimates***

An estimate of sport harvest was made through a contact creel survey conducted in the Les Cheneaux Islands area from May 1 through October 31, 1995. The creel survey was based on a stratified design using simple random sampling within strata (see Rakoczy and Svoboda 1995 for details on creel survey methods). Survey clerks also collected tag-return information.

Concurrent with the creel survey, flights over the study area were made on a random schedule (random takeoff times during daylight hours). Flights were made 5 days each week (3 randomly picked weekdays

plus both weekend days), although some flights were canceled because of weather conditions. During each of 245 flights, all boats except sailboats and commercial vessels were counted within the study area. The ratio of nonfishing boats (pleasure boats) to fishing boats was calculated using angler-party interview sheets. Count data were employed to calculate fishing effort using mean number of boats by weekday, by weekend day, and by month. Catch rates, determined from weekend and weekday interviews, were used to estimate total catch. Details concerning use of aerial boat counts for calculating fishing effort were described by Ryckman (1981).

### ***Yellow Perch Size and Age Structure***

To obtain information about population size structure of yellow perch, we measured and recorded lengths from five sources: a net-run sample of 325 yellow perch caught in 13-mm mesh fyke nets in April 1995, tagged perch, sport-caught perch measured by creel clerks, perch caught in graded-mesh gill nets, and perch caught in assessment trawls. The fyke-net sample was biased toward mature fish because sampling was performed during spring, when spawning aggregations of perch concentrated in shallow water. Likewise, length frequencies of tagged fish represented spawning-run fish that also were graded by handlers (no fish shorter than 150 mm was tagged). Lengths measured by creel clerks were influenced by the 175-mm minimum size limit for yellow perch. Gill-net catches were biased because yellow perch smaller than 125 mm were not captured in the gear. Trawling produced few fish of any size. All sampling methods collected few small fish.

As a consequence of the scarcity of small yellow perch in samples described above, there was a corresponding lack of size-at-age and age-structure data for younger fish. To put cormorant predation into a proper perspective, we needed some idea about the magnitude of these undersampled perch. Therefore, we constructed numbers of perch at small sizes and young ages by combining information from the estimated yellow perch mortality rate, population size, and the age structure of perch caught in gill nets. A tool

needed for this exercise was a length-at-age key created from yellow perch data collected from Bay de Noc, Lake Michigan, 1988 to 1995 (Schneeberger and Scott 1997). Growth of yellow perch in the Les Cheneaux Islands area and Bays de Noc appeared to be similar based on a comparison of size-at-age of larger fish, whereas small, young perch were well represented in trawl samples in Bay de Noc (Schneeberger and Scott 1997).

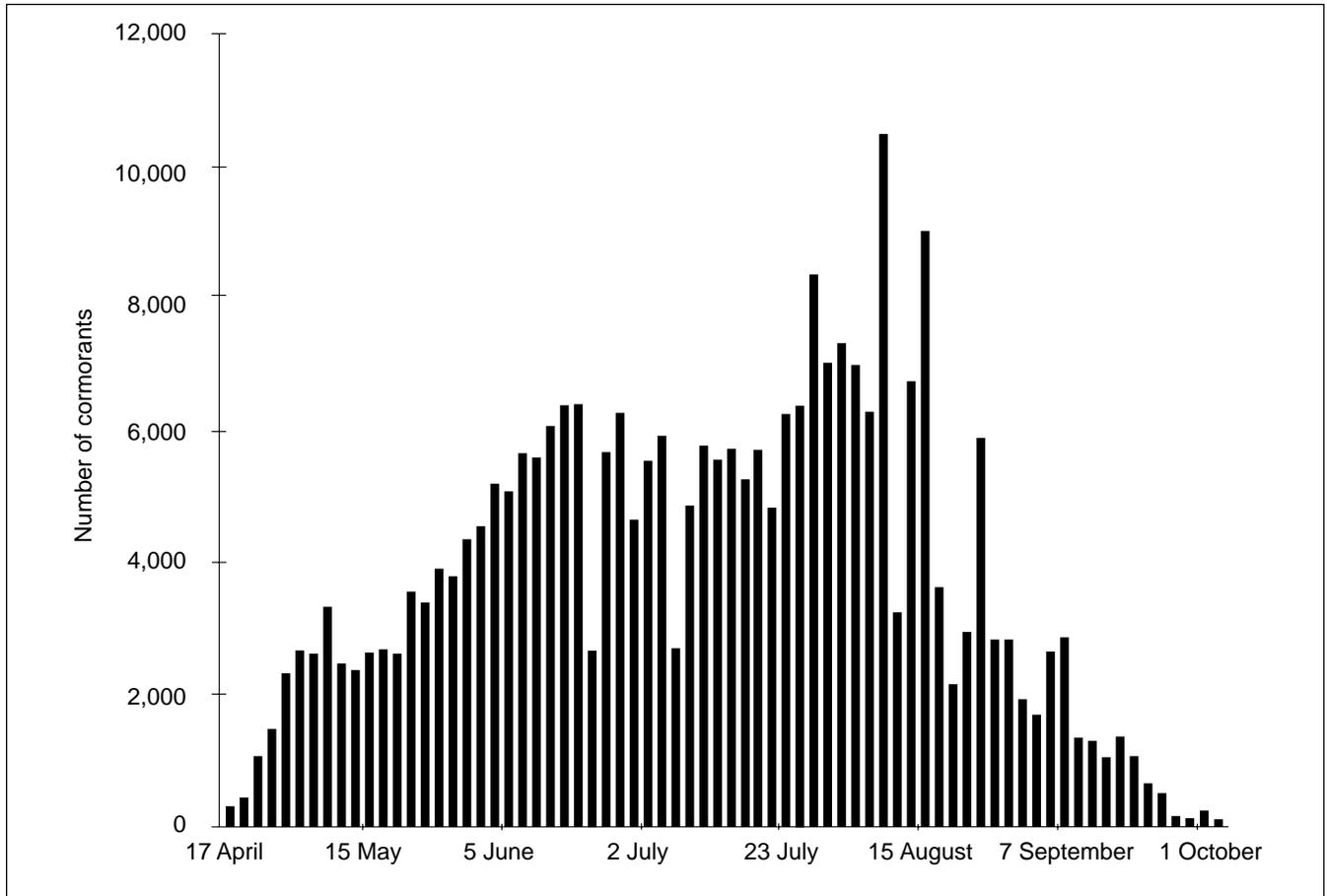
## Results

Cormorant numbers from flight records rapidly increased through April and May and then generally stabilized during June and July. Numbers climbed rapidly again in late July as young birds fledged from the nesting colonies. Numbers then declined rather sharply until nearly all birds had migrated from the area by early October (fig. 2).

Just over 4,000 nests were present at the 3 cormorant colonies (St. Martin's Shoal—1,954 nests, Goose Island—1,766 nests, Crow Island—311 nests) associated with the Les Cheneaux Islands study area.

Of the 373 cormorants collected for the food-habits study, 53 (14 percent) wore leg bands. These birds had been banded at their respective nesting colony before fledging. Birds came from nearly every known nesting colony in northern Lake Huron, northern Lake Michigan, and eastern Lake Superior (Belyea 1997b). It is not surprising in a large and rapidly expanding population such as this to have a mixing of birds from various colonies. Some of the colonies represented were surprisingly far away. The farthest colony represented was Spider Island, WI, which is about 238 km from the recovery location.

The oldest banded bird collected was 11 years old, and 25 (47 percent) birds were 5 or more years old. If young-of-the-year (YOY) birds are excluded, the average age of the banded cormorants was 5.9 years. The number of older birds would indicate that cormorants have high longevity and probably high survival. A number of the cormorants collected in late summer were young of the year. Most were from colonies within the



**Figure 2**—Aerial survey counts of cormorants in the Les Cheneaux Islands area during 1995.

Les Cheneaux Islands area, but three were from Canadian colonies in the north channel of Lake Huron. This finding demonstrates how early some young birds leave nesting colonies to begin migrating south.

Thirty taxonomic groups, encompassing 1 invertebrate and 14 fish families, were found in the cormorant diet. A number of other small invertebrates thought to be fish prey items (Johnson et al. 1997) were also found but not identified. In addition, stomach parasites, especially roundworms, were found in 64 percent of the stomachs (Maruca 1997b).

Seasonal diet composition of cormorants indicated that many of the primary diet species were spawning at the time they were consumed: yellow

perch, northern pike, rock bass, and pumpkinseed in period 1, sticklebacks and some alewife in period 2, and alewife in period 3 (table 2). Alewife was by far the most important diet item, dominating diet biomass during periods 3 to 6 (July 4 to October 6). During periods 2 to 4, most alewife consumed were spawning adults or yearling fish, but during periods 5 to 6, approximately 80 percent of the alewife captured were young of the year. Consumption of perch was highly variable with time. In terms of biomass, yellow perch made up 48 percent of the cormorant diet during period 1 but dropped substantially during periods 2 to 5 and rose again to 14 percent during period 6 (Maruca 1997b).

**Table 2. Diet composition (by percentage) of cormorants collected from the Les Cheneaux Islands area in 1995<sup>1</sup>**

| Prey group     | Period 1       |          | Period 2 |          | Period 3 |          | Period 4 |          | Period 5 |          | Period 6 |          | Total    |          |
|----------------|----------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|                | <i>N</i>       | <i>B</i> | <i>N</i> | <i>B</i> | <i>N</i> | <i>B</i> | <i>N</i> | <i>B</i> | <i>N</i> | <i>B</i> | <i>N</i> | <i>B</i> | <i>N</i> | <i>B</i> |
| Alewife        | — <sup>2</sup> | —        | 6.2      | 40.0     | 61.1     | 88.9     | 25.1     | 28.5     | 35.1     | 29.8     | 91.8     | 65.1     | 29.2     | 46.8     |
| Stickleback    | 13.5           | 0.8      | 91.4     | 46.03    | 33.8     | 5.4      | 21.3     | 3.3      | 38.4     | 8.4      | 0.7      | 0.2      | 57.9     | 15.1     |
| Yellow perch   | 42.1           | 47.7     | 0.2      | 1.2      | 0.4      | 0.9      | 1.6      | 7.0      | —        | —        | 0.4      | 13.9     | 2.1      | 10.5     |
| Centrarchid    | 9.4            | 14.7     | 0.2      | 2.7      | 0.1      | 0.2      | 1.1      | 11.9     | 1.7      | 15.1     | 0.6      | 3.8      | 0.8      | 6.3      |
| Sculpin        | 0.3            | —        | 0.6      | 1.0      | 1.4      | 0.6      | 41.7     | 23.6     | 15.3     | 11.8     | —        | —        | 5.0      | 4.0      |
| Northern pike  | 2.8            | 18.1     | —        | 2.5      | 0.2      | —        | 0.3      | 0.3      | —        | —        | —        | —        | 0.2      | 3.9      |
| Minnnow        | 24.0           | 4.1      | —        | —        | 0.3      | 0.2      | 1.6      | 1.1      | 3.7      | 2.3      | 4.7      | 9.2      | 2.1      | 1.6      |
| White sucker   | 1.7            | 11.7     | —        | —        | 0.1      | 1.9      | 0.8      | 12.0     | 0.2      | 8.5      | —        | —        | 0.2      | 4.8      |
| Brown bullhead | 0.8            | 2.4      | —        | —        | —        | —        | 0.8      | 9.7      | 1.0      | 19.4     | —        | —        | 0.2      | 3.4      |
| Smelt          | 0.8            | —        | 0.5      | 0.4      | 1.8      | 0.4      | —        | —        | 0.5      | —        | 0.1      | —        | 0.7      | 0.2      |
| Salmonid       | —              | —        | 0.1      | 1.3      | 0.2      | 1.4      | —        | —        | 0.2      | 0.7      | —        | —        | 0.1      | 0.9      |
| Crayfish       | 3.3            | 0.2      | 0.4      | 0.2      | 0.2      | —        | 4.4      | 0.8      | 1.7      | 0.4      | —        | —        | 0.9      | 0.2      |
| Unidentified   | 0.6            | —        | —        | 0.1      | 0.2      | —        | 0.8      | 0.4      | 0.5      | 0.3      | 0.1      | 0.1      | 0.2      | 0.1      |
| Other          | 0.8            | 0.1      | 0.1      | 4.5      | —        | —        | 0.2      | 1.5      | 1.6      | 3.2      | 1.5      | 7.5      | 0.4      | 2.1      |

<sup>1</sup> Values are percentage by number (*N*) and biomass (*B*) of prey items from each prey category for each dietary period.

<sup>2</sup> A dash represents less than 0.1 percent.

The biomass of yellow perch consumed by cormorants was estimated at 7,100 kg during perch spawning (period 1) and 4,300 kg during the remainder of 1995, for a total of 11,400 kg consumed. Given the size frequencies of perch in the diet and mean weights for each size class, these biomass estimates correspond to a range of 270,000 to 720,000 individual perch consumed with a best estimate of 470,000 (Maruca 1997b). Only about 5 percent (24,000) of these perch were of legal size (length > 175 mm) when consumed (range, 14,000 to 37,000 fish). Cormorants also consumed an estimated 7,000 to 17,000 YOY perch during periods 2 to 6. No estimates of YOY perch abundance were made during 1995, so the exact effect of cormorant predation on recruitment is unknown. However, recruitment of YOY to yearling perch is highly variable throughout the Great Lakes and does not appear to be correlated with the presence of avian predators. Furthermore, given the size of other year classes for Les Cheneaux Islands perch (Schneeberger and Scott 1997), it seems reasonable

to assume that removal of up to 17,000 young of the year would have no substantial effect on recruitment. The calculations of mortality rates that follow do not include YOY perch.

Mortality of legal-size perch due to cormorant predation and summer sport fishing in 1995 was low when compared with all other sources of mortality combined. There appeared to be 2.76 million yellow perch of legal size in the Les Cheneaux Islands area in 1995 (Schneeberger and Scott 1997), so by consuming 24,000 legal-size perch, cormorants removed only 1 percent of the population. Angler catch was estimated at 66,500 (Schneeberger and Scott 1997), which gives a summer angler exploitation rate of only 2.4 percent. The total annual mortality rate for the yellow perch population was estimated at 45 percent (Schneeberger and Scott 1997). Other sources of mortality must then remove roughly 40 percent of legal-size perch to account for total annual mortality of 45 percent.

Examination of size-specific mortality rates reveals that mortality from cormorant predation is heaviest at smaller sizes (75 to 175 mm in early spring and 75 to 100 mm during the rest of the year). Mortality from angling is greatest at fish lengths of 175 to 200 mm. It is not surprising that cormorants and anglers remove different sizes of perch because anglers are restricted to larger fish by the 175-mm size limit, and cormorants have been shown to consume smaller fish even when larger fish are available (Campo et al. 1993). Neither cormorant predation nor angling is a significant source of mortality at any size or time of year when compared with total annual mortality (45 percent).

Examination of mortality rates by ages reveals that even the highest estimate for cormorant consumption of perch yields mortality rates that are less than 10 percent for all ages, which accounts for about one-fifth or less of the total annual mortality (45 percent). Mortality from summer angling is less than 3 percent for all age classes, which is less than one-fifteenth of total annual mortality. Because cormorants and anglers consume different sizes of perch, they affect different ages as well, although the overlap is greater for ages than for sizes. In general, cormorant predation accounts for a greater proportion of mortality at younger ages (1 to 3), whereas anglers mainly take perch 3 years old and older.

## Discussion

Although the cormorant diet contained approximately 48 percent yellow perch, by weight, during the perch spawning season, the results for this study suggest that cormorant predation of perch in 1995 was, on the whole, not substantial. Other sources of mortality, therefore, accounted for the majority of yellow perch deaths. Little data exist on the consumption rates of perch by other fish in the Les Cheneaux Islands area; however, burbot (*Lota lota*), northern pike (*Esox lucius*), and splake (*Salvelinus namaycush* × *S. fontinalis*) are common large fishes in the area that have been reported to feed on yellow perch (Scott and

Crossman 1973) and could consume moderate-to-large perch. Furthermore, many medium-sized fish in the area, such as smallmouth bass (*Micropterus dolomieu*), rock bass (*Ambloplites rupestris*), brown bullhead (*Ameiurus nebulosus*), and pumpkinseed (*Lepomis gibbosus*), may prey on juvenile perch. Native American commercial gill netting, common in the Les Cheneaux Islands area, is another possible source of mortality; however, most effort takes place south of the main islands in deeper water, where perch are likely to be scarce. There were no reports of tagged perch recovered by Native American fishermen, which suggests that mortality from gill netting was minimal.

An important consideration in interpreting the results of this study is year-to-year variation in cormorant consumption of perch and its effect on perch population dynamics. Specifically, the timing of perch spawning relative to cormorant migration may affect the number and sizes of perch that are vulnerable to heavy cormorant predation. In 1995, northern Michigan experienced a warm spring; as a result, perch spawning occurred earlier than usual. Many of the larger spawning fish may not have been susceptible to cormorant predation because they had spawned and dispersed before cormorants arrived in the area. However, in 1996, spawning was late and peaked after many cormorants had already migrated into the study area. Perch may have comprised a greater proportion of the cormorant diet or may have been represented by a different size distribution in 1996 compared with 1995 (Maruca 1997b).

The relative contributions of different sources of mortality of perch, as well as total annual mortality, may also vary annually. Lucchesi (1988) and Schneeberger and Scott (1997) used comparable techniques to estimate total annual mortality in 1986 and 1995, respectively. Total mortality was 55 percent in 1986 and 45 percent in 1995. These differences may represent a gradual decline in mortality over the last decade, substantial yearly fluctuations in mortality rates, or differences in sampling bias. The composition of these mortality rates has changed substantially: Lucchesi (1988) estimated that in 1986 fishing mortal-

ity for adult perch may have been as high as 40 percent, whereas in 1995, Maruca (1997b) estimated fishing mortality to be no greater than 5 percent.

There may also be variation in total annual mortality of perch across ages. Because different factors affect mortality at different ages, it seems likely that age-specific total mortality rates will differ. Catch curve analysis (Schneeberger and Scott 1997), a standard fisheries technique, assumes that mortality rates do not differ by age. This assumption may be reasonable for older fish, which are less size differentiated, less affected by physical factors, and more uniformly susceptible to predation. All these factors may result in similar and stable mortality rates. Mortality for younger perch is likely to be higher, more variable, or both. Cormorants may occasionally be a more prominent source of mortality for these ages, depending on their density and the relative additivity of all sources of mortality.

We know little about the indirect or higher order effects that cormorants have on target populations (such as perch) or on other components of these aquatic systems. For example, cormorants prey on northern pike (pike make up 18 percent of the diet by biomass in period 1), a known predator of yellow perch, thereby introducing an indirect positive effect on perch. Alewife are widely abundant throughout lakes Huron and Michigan and have been the object of numerous control strategies; these fish are also the primary prey for cormorants nearly everywhere the two species are found together (Belonger 1983 unpubl., Christie et al. 1987, Ludwig et al. 1989, Karwowski et al. 1992, Ross and Johnson 1995). Predation on alewife may alleviate competition with yellow perch, as well as predation by alewife on perch larvae.

On the basis of the same bioenergetics approach used earlier to estimate consumption of perch, we estimate that in 1995 cormorants consumed approximately 123,000 kg of alewife in the Les Cheneaux

Islands (Maruca 1997b). Because no population or total biomass estimates were made for alewife in this area, the impact of this level of cormorant predation cannot be known. Cormorant reproductive success may be intimately linked to the alewife populations and fluctuations therein (Weseloh and Ewins 1994). This theory suggests that (1) abundant alewife have contributed to widespread cormorant population growth and (2) if food limitation is to occur for cormorants, it may be controlled by the alewife population. Cormorants may be indirectly benefiting yellow perch and many other components of the ecosystem by preying heavily upon the exotic alewife.

## Management Implications

A potential concern with cormorants may be their effect on small fish. In particular, fish 75 to 125 mm in length appear to be more uniformly vulnerable to cormorants. However, it is not clear whether mortality of small perch caused by cormorants occurs in addition to other substantial sources of mortality (additive) or rather replaces these other sources (compensatory). If mortality from cormorant predation is additive to other sources of mortality at small sizes, the future abundance of large fish could possibly be reduced, although current predation rates suggest that this effect will not be substantial.

We conclude that reasonable year-to-year variation in cormorant predation of perch during perch spawning will not drastically alter age-specific mortality rates, provided perch and cormorant population sizes are comparable to 1995 estimates. However, over the long term, changes in predatory behavior of cormorants, ecological plasticity regarding the timing or location of perch spawning, and population fluctuations for either cormorants or perch may influence the importance of yearly variation in predation.

The depressed population of yellow perch is not unique to the Les Cheneaux Islands but has been observed in many other areas of the Great Lakes. Abundance of perch in the Les Cheneaux Islands was low during 1985 to 1994, but fall gill-net surveys indicate an increased catch-per-effort in 1994–95. There also appeared to be several strong year classes in the population (1989, 1991, and possibly 1993 year classes). However, preliminary 1996 gill-net data indicate the lowest catch per effort in recent times. These results make it difficult to forecast perch population trends in the Les Cheneaux Islands area.

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## Directory of Personal Communications

Frank Chenier  
U.S. Geological Survey  
Escanaba, MI